



# Radio Frequency Weapons

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*Prepared and presented by*

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•Good \_\_\_\_\_ Ladies and Gentlemen, today I am going to Discuss the highly debated topic of Radio Frequency Weapons, their threat to the military and civilian infrastructure, and some general RDT&E issues associated with the technology.

## OVERVIEW



- *What are RF Weapons?*
- *RF Weapons Effects*
- *Applications and Doctrine*
- *Types of RF Weapons*
- *Technology Issues*
- *Status and Future*
- *RDT&E Issues*

As we go through this brief please keep the concept of intent as a key issue.

Intent ! The difference between a transmitter and a Death Ray is intent (malice)

## Background



### **Recent Congressional - Joint Economic Committee Hearings Have Brought Public Attention to Radio Frequency (RF) Weapons.**

- *Futuristic weapons have always been a popular subject*
  - Current interest high
  - Confusion over what is meant by various terminology
- *Briefing is a general discussion of RF weapons*
  - From Electromagnetic Environmental Effects perspective
  - Intended to foster thought and encourage discussions
- *All technical information discussed can be found in open literature*

• On Feb 25, 1998 Congress held Joint Economic Committee Hearings to discuss Radio Frequency Weapons and the impact these weapons could have on our economy. There is growing concern that hostile forces or individuals could attack our national infrastructure with a new class of weapons and cause devastating effects..

The Committee was chaired by Representative Jim Saxton (R-NJ) Panelists included Alan Kehs, Army Research Lab, Jim O' Bryon Director LFT, Dave Shriner, a former employee of China Lake and Ira Merritt of the Army's SMDC.

The panelists all agreed that while no evidence exists to prove that an RF weapon has been used, the emergence of this new class of weapons is just a matter of time.

• So, these futuristic weapons have made it into the hallowed halls of Congress. Has anything changed to make interest in these threats more than a passing fad? And exactly what is a Radio Frequency Weapon or RFW? Since the evidence to prove these weapons exist isn't available, what are we talking about ?

• This briefing provides a general introduction to RF Weapons. Since my background is Electromagnetic Interference(E3) I will bias this presentation accordingly. Don't plan on walking out of here with the answers, I hope at best to foster some serious thought about the subject, spark some lively discussions and perhaps with luck leave you all a little better educated. Caused by a lot of speculation about RF weapons this brief is intended to provide perspective as it relates to the subject presented at these JEC Committee

• There is plenty of information available, under a variety of different descriptions. The easiest source of information is the internet. There are many sites, official and unofficial sites. I do not guarantee the validity of that information. You will find a wide range of views on the internet, ranging from the fringe elements and science fiction community to serious scientists and businesses.

## RF Weapons Threat



- ***RF Weapons may pose threat to US Military and Civilian Infrastructure particularly Commercial Off-the-Shelf (COTS) and Non-Developmental Items (NDI).***
  - Command and Control
  - Communications
  - Information Systems
  - Navigation
- ***RF Weapons technology available on open market***
  - Buy it, Build it, Open Source Availability
- ***Most work to date is classified - this program makes information available to decision makers***

***RF Weapons provide potential for Asymmetric Advantage***

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### The RF Weapons Threat

The concern over RFW threats is increasing. Congress has conducted several hearings into this issue. The increasing reliance on, and leadership in, information technology makes the US particularly vulnerable to potential RF weapons threats. The General civilian and government infrastructure vulnerability may be at risk to future threats.

RFW technology is becoming more and more available to potential adversaries. The Equipment, skills and resources necessary for deploying such a device is no longer limited to large research and development efforts. RF Weapons can readily bought or built. A considerable inventory of devices is available on the open market, which may have applications as a weapon. Most importantly, the performance parameters of such systems continues to expand as advances in all aspects of weapons subsystems improve daily.

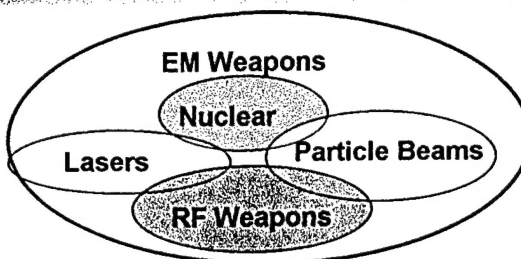
If there is information available on susceptibility / survivability data for systems, it is highly classified. As part of assessing general DOD and National preparedness against such threats, data must be obtained that is non anecdotal, and operationally relevant. Furthermore, this data must be available to decision makers to assist in planning and preparation.

The RFW has the potential for asymmetric advantage. They must be evaluated for effectiveness to help prepare DOD for future Threats.

# What are RF Weapons?



A class of weapons (sources) whose intent is to disrupt / disable / destroy an adversary's device / system by means of some intense electromagnetic (EM) environment.



- RF Weapons Are:
  - In the Radio Wave Spectrum (DC through Gigahertz)
  - Can be Highly Directional (Beams) or Isotropic (Omni- Directional)
  - Created through variety of methods ( primitive ➡ Nuclear EMP )
- RF Weapons Are NOT:
  - Ionizing (No Nuclear fallout, or radioactivity)
  - Near visible Spectrum (lasers or Infra-red, Ultra-violet)

Question: Does High Power Microwave (HPM) = RFW ?

•We should begin with definitions. What exactly are RF Weapons? ***“A class of weapons (sources) whose intent is to disrupt / disable / destroy an adversary's device / system by means of some intense electromagnetic (EM) environment..”***

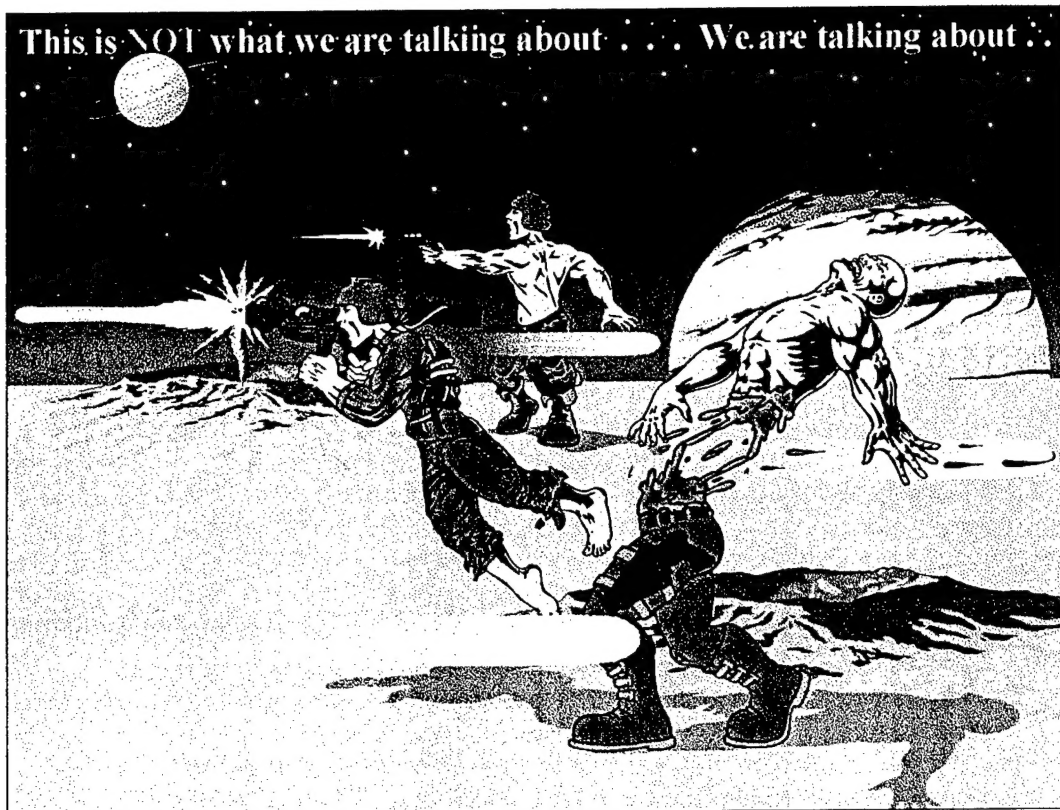
•RF weapons are part of the larger family we can call EM weapons, Lasers, Particle Beams, and Nuclear Weapons are familiar examples. Since all EM weapons are related the separation and distinction is somewhat arbitrary. However, for our discussion RF Weapons are easily defined.

•What are some of the attribute of an RF Weapon:

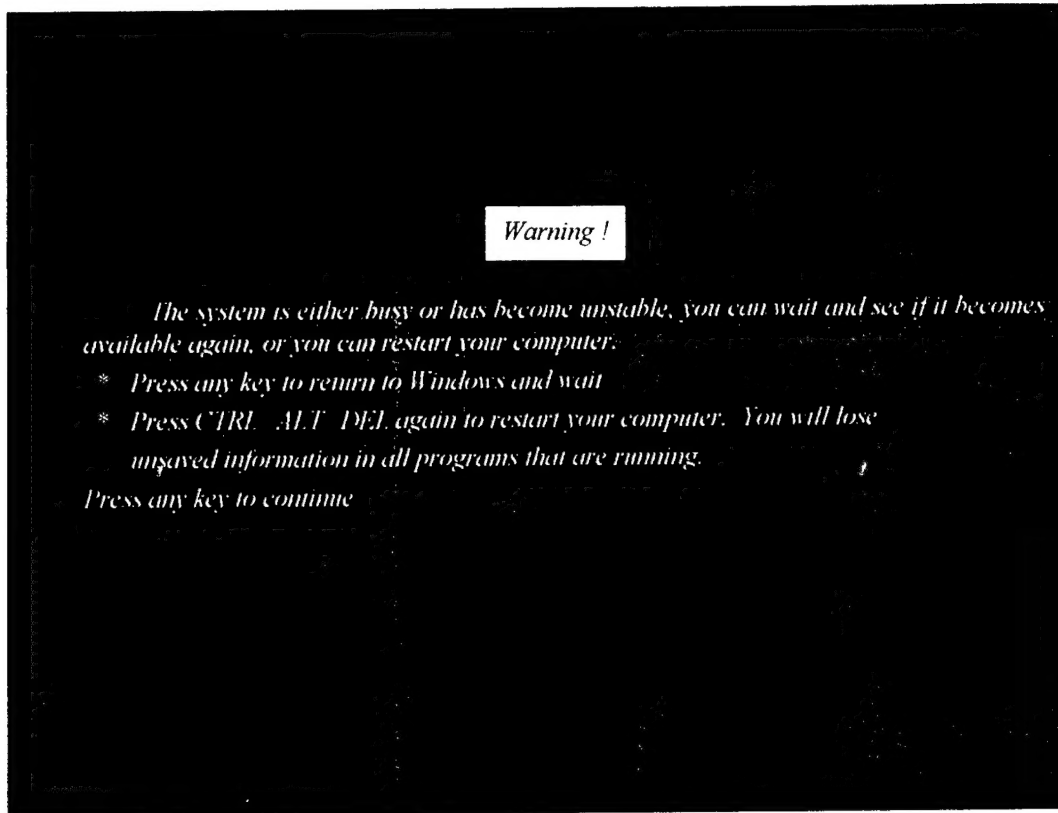
- Well, they generate EM signals in the radio wave region which includes power, communications and radar frequencies.
- The energy can be transmitted through a beam, or transmitted in all directions or something in between.
- And the weapon can be as crude as a kids science project or as complex as a nuclear weapon.

•To understand what these weapons are we must also decide what they are not.

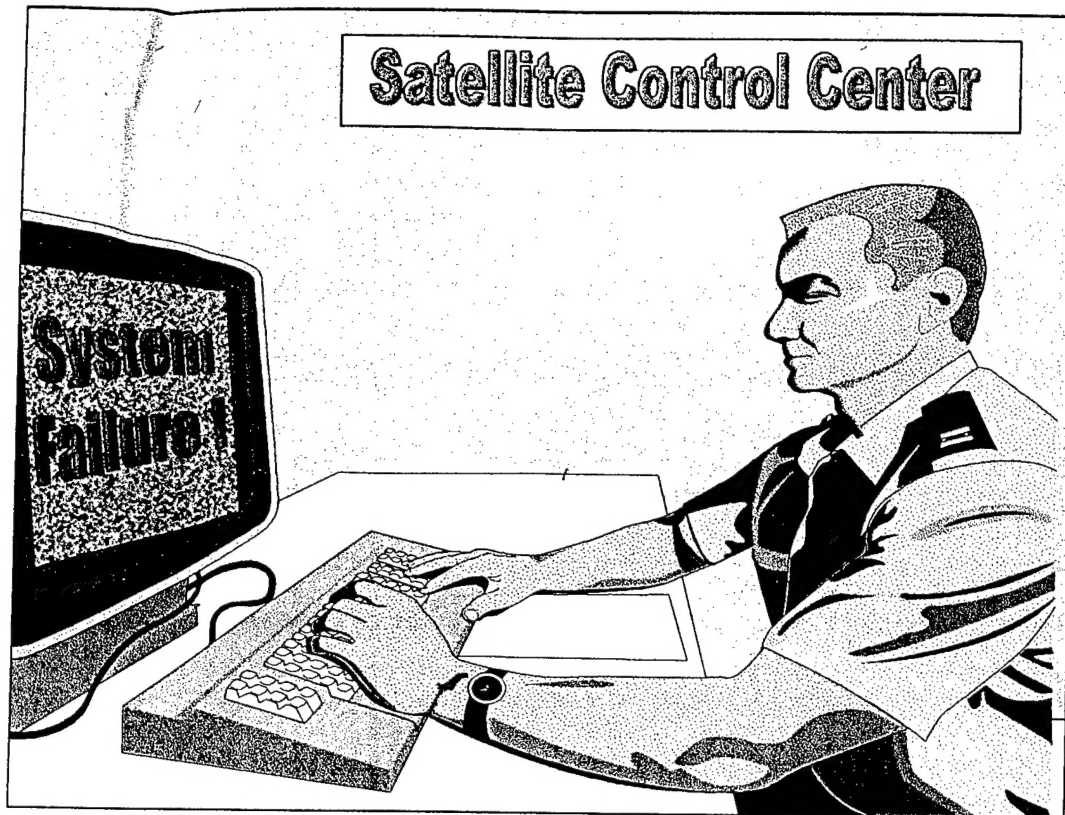
- They are not ionizing. There is no lingering radiation, or fallout or radioactive residues to contend with.
- They are Not lasers, or similar systems which operate in the or around the visible part of the spectrum.



For you Sci-Fi buffs in the audience, I'm sorry to announce we won't be discussing many of the exciting aspects of RF weapons as depicted in the entertainment industry. While its fun to speculate on where science will take us in the distant future, we have some weapons that could be deployed very soon. For example:

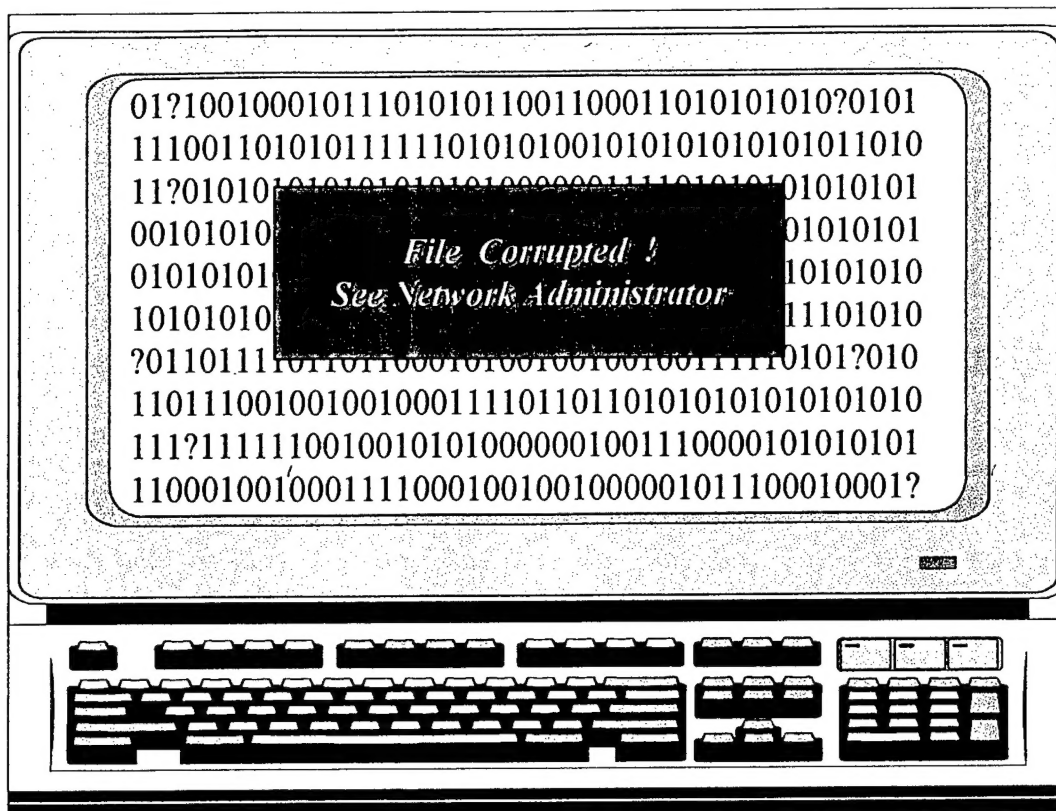


Most of you are familiar with the Bill Gates greeting from Redmond Washington. Many of us have become so numbed to this screen that we would never suspect a criminal, terrorist or military action could be taking place. If it is possible to bring your system back up, it may be too late. Are you oblivious to sinister forces at work, or is this just another harmless gremlin?

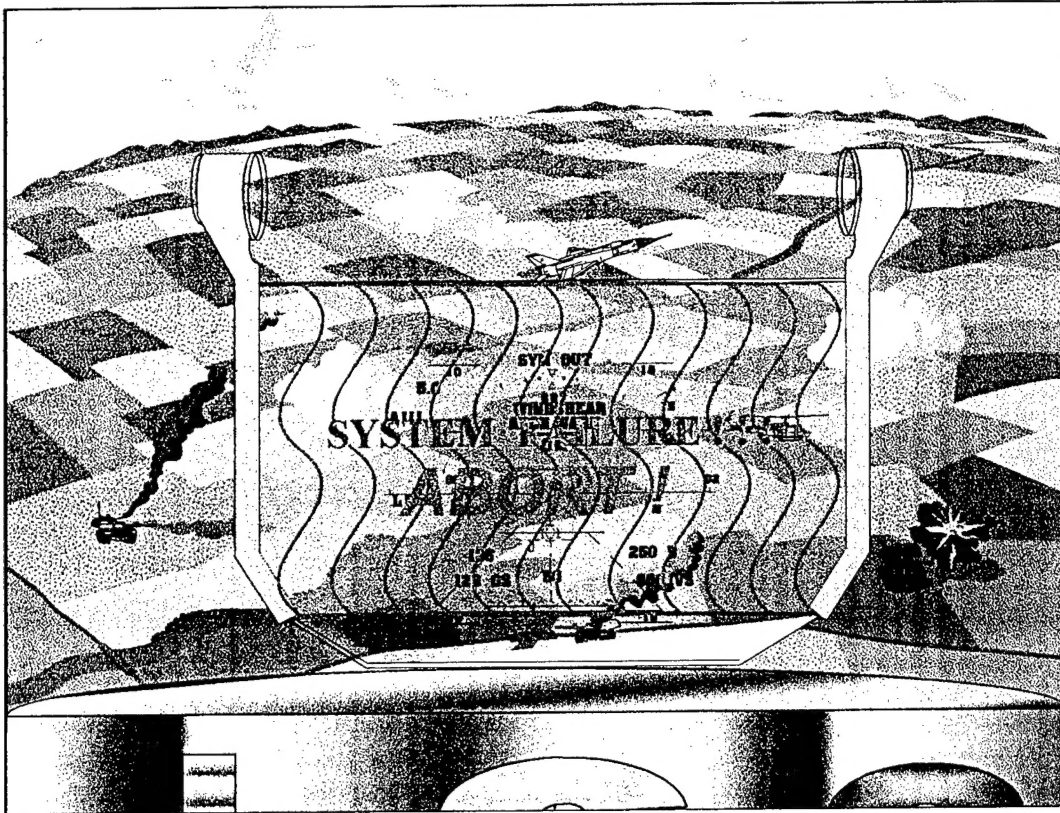


As our small soldier is finding out, the system interruption is neither normal or temporary. An adversary thousands of miles away could have blinded our satellites, seriously degrading our information superiority advantage.

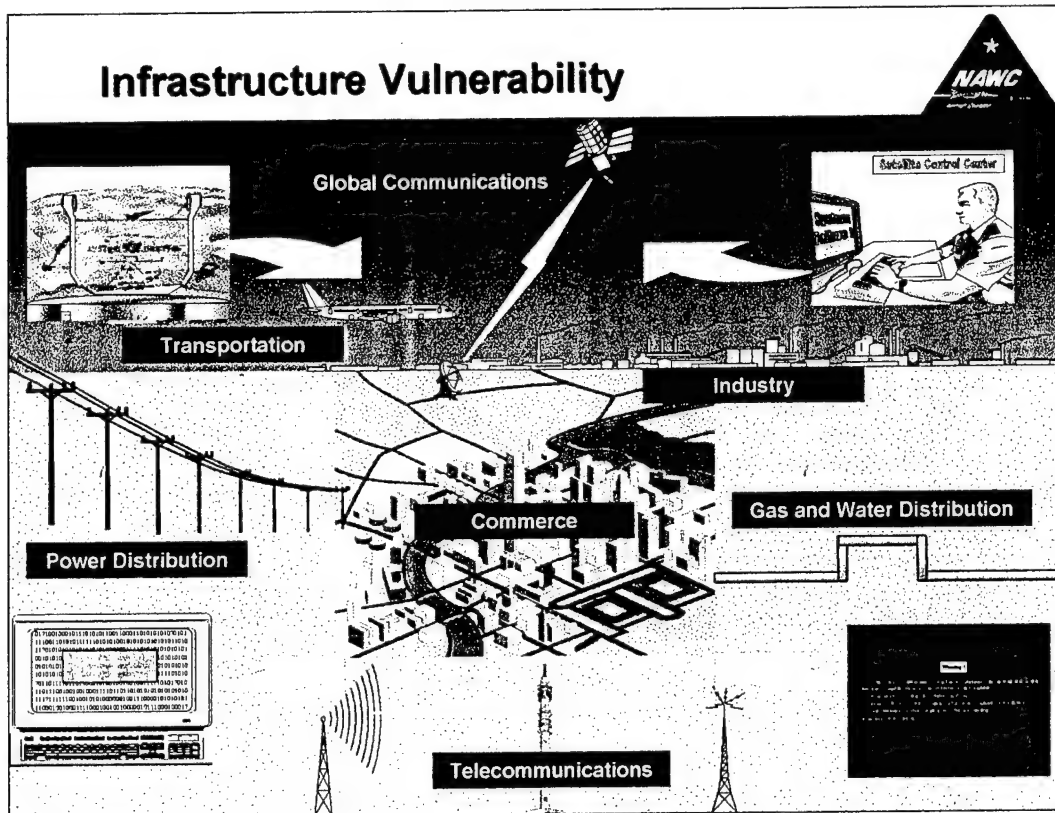




Not just a file is being destroyed, the majority of your data repository. Meanwhile at your remote archive site many miles away, your backup data is being irrecoverably destroyed. The culprits could have made off with millions of dollars and used this to cover up their tracks. The data was priceless. Next time your management will take extortion demands seriously.



Sometimes, rebooting is not an option, As shown here, External Radio Frequency signals are affecting the pilots Heads up display, The signals may also be affecting the aircraft's digital flight control systems of this fly by wire aircraft. In this futuristic scenario, the computer operators day is completely ruined.



There are certainly plenty of examples of how RF Weapons **COULD** be used today or in the near future. But the point is that IF RF Weapons aren't real today, they will be tomorrow. We as a nation are extremely dependent on information and potentially vulnerable to the effects of hostile attacks on our infrastructure. The concerns which prompted congress to establish committees to address this issue are not military. It is the National Infrastructure. Utilities, communication, transportation, commerce, all are vulnerable. In fact, Few activities are prepared to cope with even some of the more amateur devices which could be fielded. The economic losses from coordinated assaults could be enormous. Finding the culprits could be difficult and serious incidents may go undetermined as to both cause and effect. RF Weapons create RF Interference, but create it on demand and with destructive power, this disrupts the flow of information; and information is money and time and perhaps, lives.

## **RF Weapons in Information Warfare**



- ***U.S. leads the world in information technology***
- ***Although militarily mighty, our nation relies on information superiority***
- ***We're most vulnerable in terms of potential effects***
- ***Speed of decision making increasing***
- ***RF considered a critical battle area in IW***
- ***To maintain Information Superiority we must protect our information and Infrastructure***
- ***Information is the new "high ground"***

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We possess the majority of the worlds computers.

89% of internet content

protect our information while denying the enemy his

situational awareness

The more you rely on information, the more critical it becomes

Increasing complexity and interconnectivity

Even the American foot soldier of tomorrow will be a walking console

## Applications and Doctrine



- *What are the benefits of RF Weapons?*
- *How would you use them?*
- *Will it work?*
- *How will you know it worked?*

Are RF weapons worth pressing

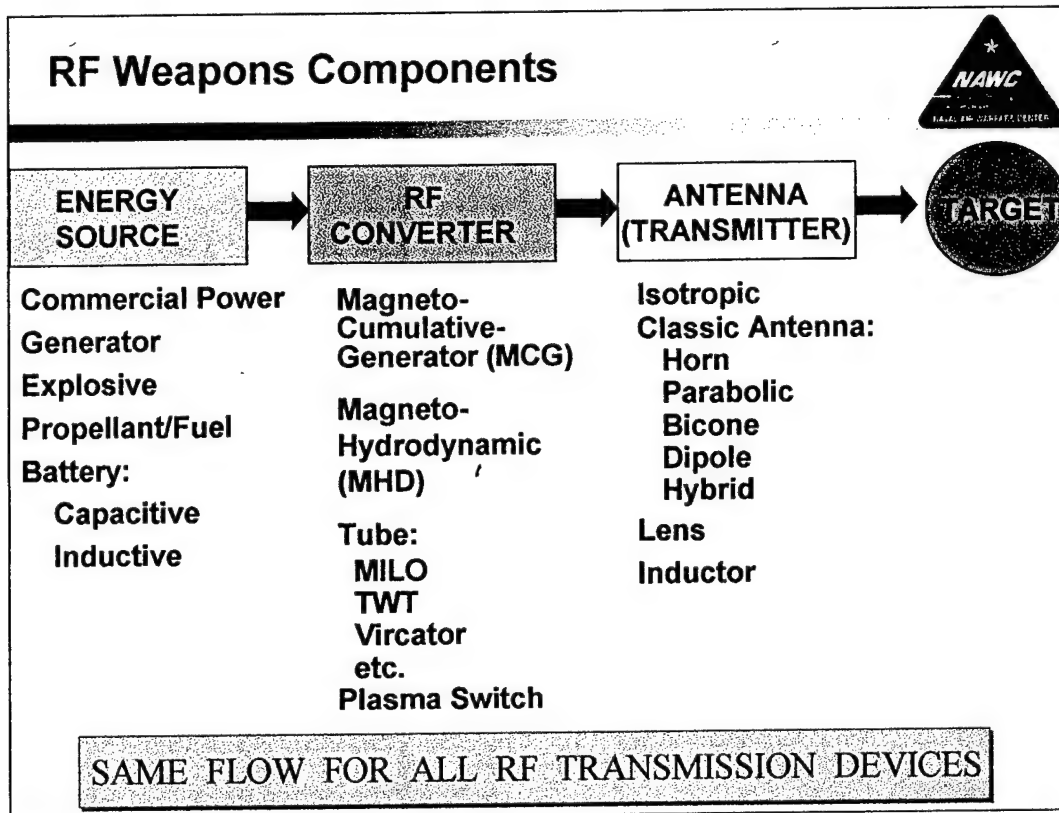
Are they better than throwing lead or more classical devices at your adversary

What are the Likely scenarios

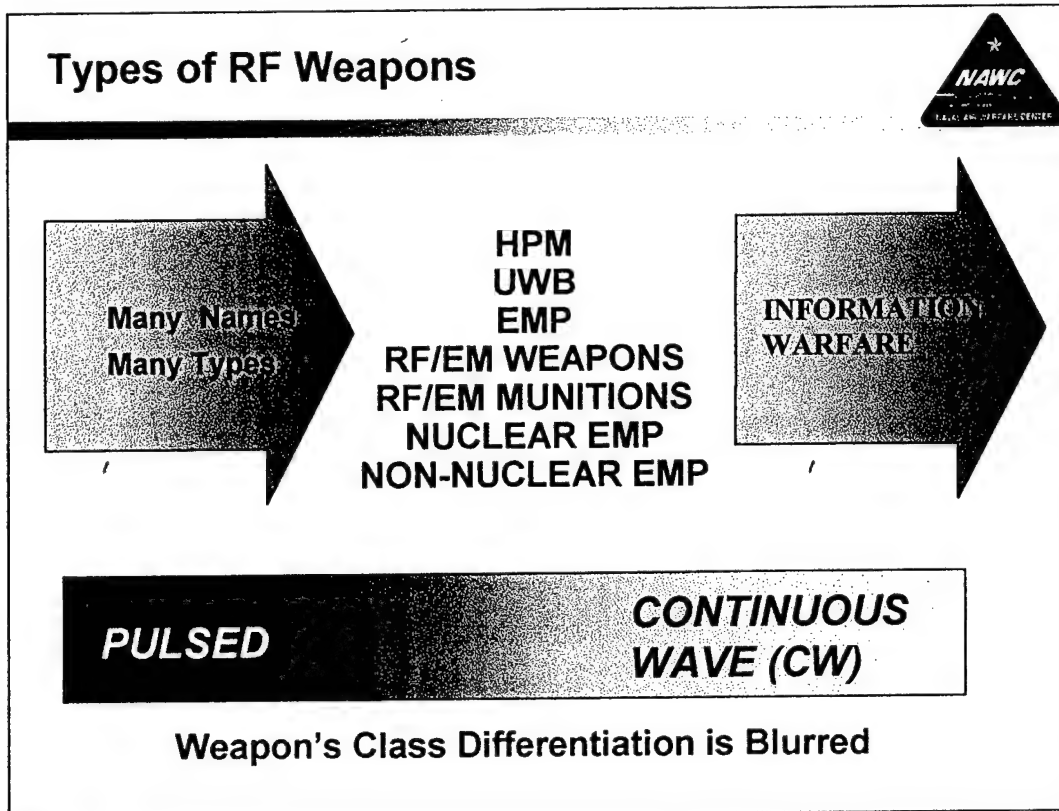
How would a terrorist / vandal / extortionist use them

The hardest question is how can you be sure your weapon worked

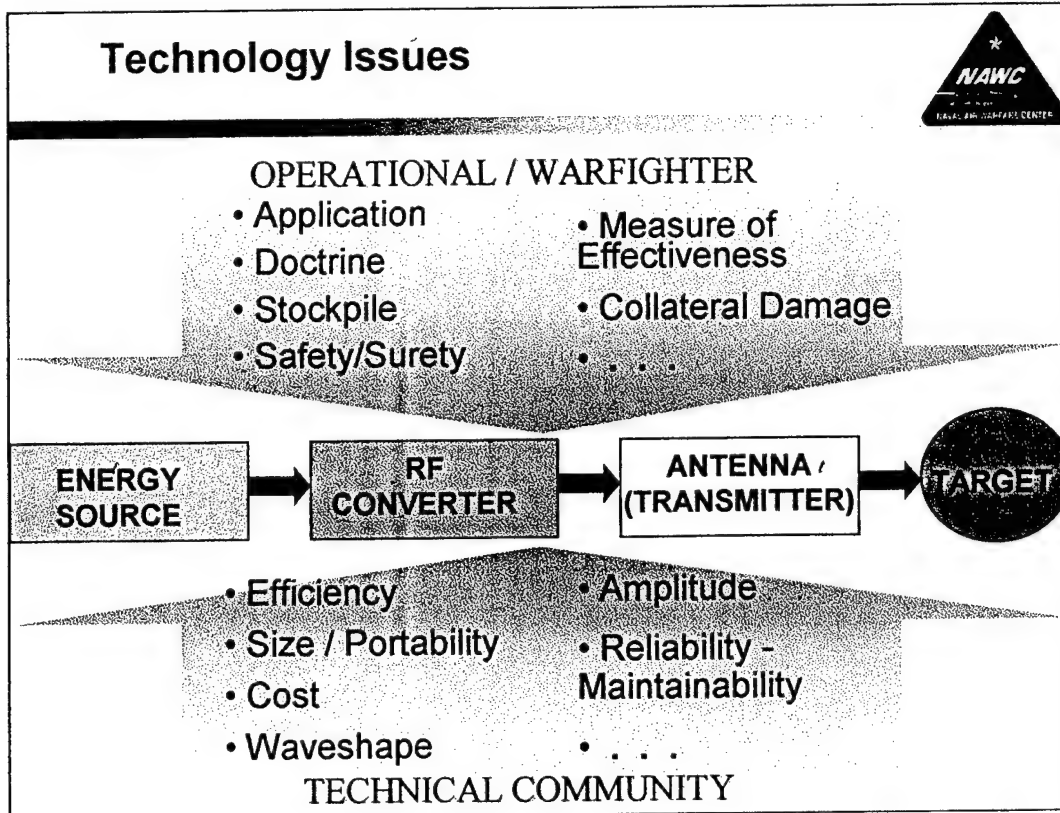
May not be any visible signs of effects



Same for RF Comm etc



CW Emitters can send out pulse trains and can have high bandwidth  
Pulsed systems can have any number of waveforms a munitions could conceivably send out multiple pulse trains before expanding its power



Many issues associated with EM Weapons apply to other areas such as EW, Radar Communications, E3, System safety etc.



## Applications (Benefits)



- ***Offensive***
- ***Defensive***
- ***Reduced Collateral Damage***
- ***Speed of Light / Line-of-Sight***
- ***Rapid Firing and Retargeting***
- ***Deep Magazines (Infinite Ammo)***
  - 
  - 
  -

Won't go into too much detail here the internet is full of speculation!!!!

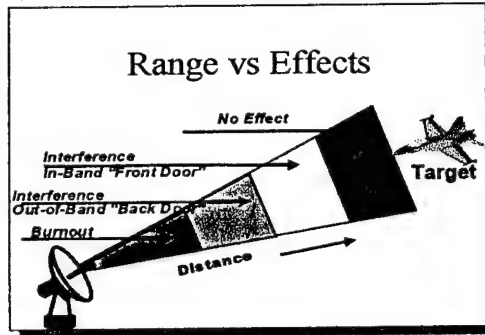
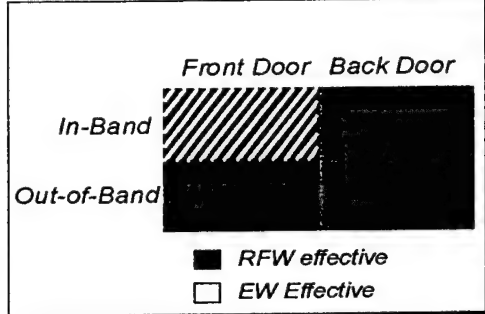
# RF Weapons Effects



## How they work

### RFW vs E3 and EW

- EW
  - Effect lasts as long as exposure
  - requires high target intelligence
  - attacks specific target components/sensor "front door"
- RF Weapons (HPM)
  - Higher Power
  - Effects continue after exposure has ended !!!!!!!!!
  - Less target specific intel required, attacks system as if it were an antenna "back door"
- E3 - INTENT!!!!
  - EW and RFW are intentional interference
  - EMI is unintentional Interference



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## What are RF Weapons

A class of weapons (sources) whose intent is to disrupt / disable / destroy an adversary's device / system by means of some intense Radio Frequency RF environment.

Lets put RF weapons into perspective as an E3 / EMI issue.

Regardless of the form a weapon may take, as long as it is in the frequency range and bandwidth of other EM environments. we will use the same E3 tools to protect our system.

In many scenarios the only difference between RF Weapons and RADARS and Comm Equipment is INTENT! Maxwell's equation are applies uniformly.

## RFW is Different from classic Electronic Warfare ( EW )

### EW

Effect lasts as long as exposure  
requires high target intelligence  
attacks specific target components/sensor "front door"

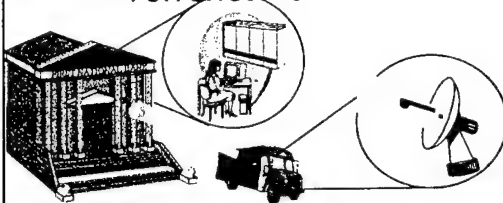
### RFW

Higher Power  
Effects continue after exposure has ended  
Less target specific knowledge required, attacks system as if it were an antenna "back door"

# RF Weapon Uses



## Terrorist / Criminal

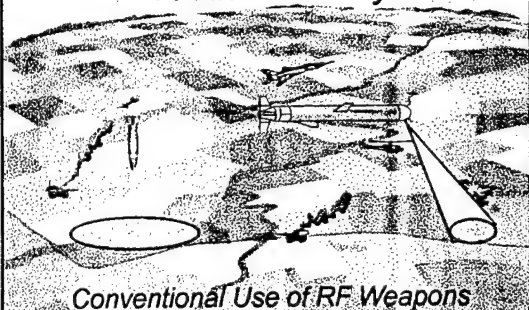


Excess Military Equipment or  
"Radio Shack" Technology

## Police / Military Operations

Covert Missions and Special Tactics

## Tactical Military



Conventional Use of RF Weapons

## Strategic Military



High Altitude Nuclear EMP

- The scenarios in which RF Weapons can be deployed is only limited by the imagination.
- Although many may argue whether the technology exists. If it does exist, it is not yet practical or affordable for most.
- As this chart shows, the terrorist attacks on "soft" targets on of the most primitive forms of RF Warfare. Such an attack could be carried out with the victim unaware that an attack has occurred. The equipment used could be excess military components, a home brewed RF transmitter, or a fairly sophisticated military grade4 weapon.
- For Police and Military operations there are many non-violent applications such as zapping vehicles or defeating security systems.
- For the tactical Military Application RF Weapons can be considered an extension of classic Electronic Warfare. New Electronic attack weapons will yield higher powers at longer ranges and disrupt systems in ways today's EW systems cannot.
- The ultimate RF Weapon for the foreseeable future is High-altitude EMP, were an intense RF environment is generated aver large areas of the earth when a nuclear weapon is detonated in the upper atmosphere. Many military systems are protected against this threat which is estimated by some to be 50,00 V/m over large geographic areas.

## Program Overview - RF Threat



- **Hostile use of RF sources [High Power Microwave (HPM)/ Radiofrequency Weapons (RFW)] may pose threat to US Military and Civilian Infrastructure particularly Commercial Off-the-Shelf (COTS) and Non-Developmental Items (NDI).**
  - Command and Control
  - Communications
  - Information Systems
  - Navigation
- **RF Weapons technology available on open market**
  - Buy it, Build it, Open Source Availability
- **DOT&E (LFT&E) Concerned about emerging non-traditional non-ballistic RF threats.**
  - Terrorist
  - Rogue Nations
  - Asymmetric Warfare

***RF Threats Provide Potential for Asymmetric Advantage  
and Could Result in "Technological Surprise"***

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## Doctrine



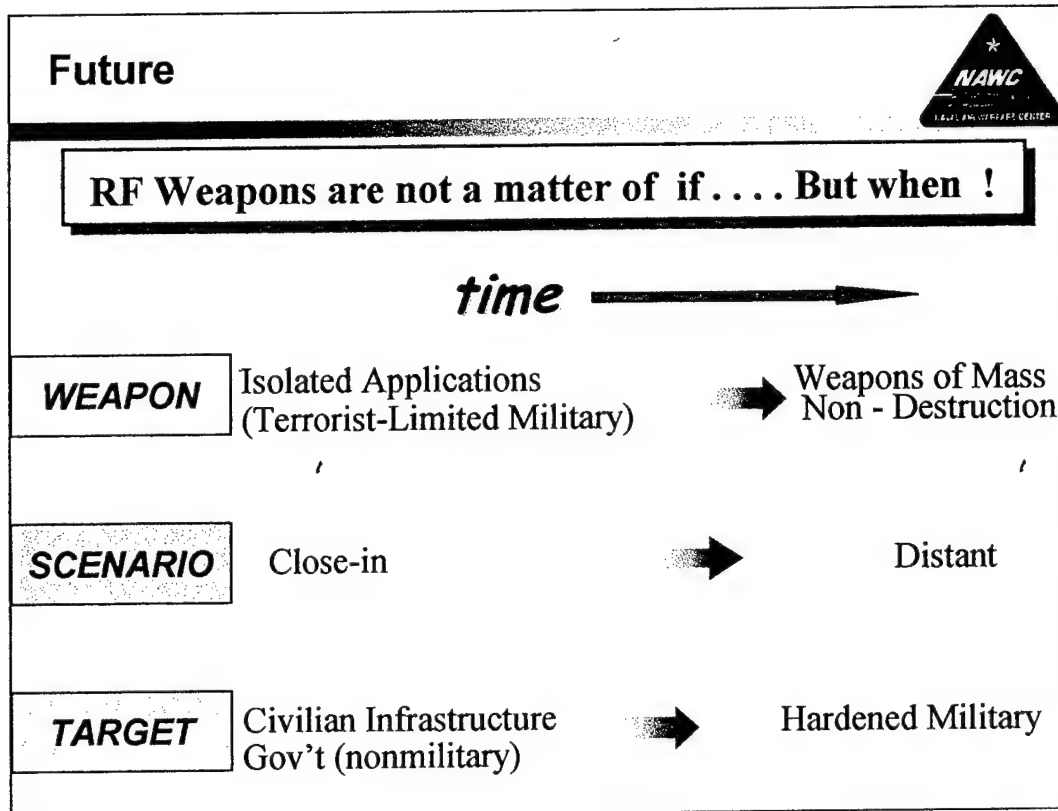
- ***Great Terrorist Weapon !***
- ***EM Weapons Crucial to Information Warfare (IW)***
  - Controlling information while denying the enemy his C3I is the cornerstone of IW
  - Information superiority is the high ground of the modern battlefield
- ***Valuable in Both Full Conflict and Operations Other Than War.***
- ***Examples:***

Gulf War - CNN reported continuously

EM weapons attacking C3I nodes in city centers would have decapitated leadership without collateral damage ( would have wiped out CNN as well)

While still defeating the soldiers in the field the old fashioned way.

At EUROEM in Bordeaux France a Russian General Lobarev made statements about a beer can sized RF munition While in Albuquerque in 1996 the general discussed the threat of RF terrorism and gave 4-case scenarios



CNN will have the most survivable equipment in theatre

Scenario most dangerous

JEC Capital Hill

COTS

EM Weapons since 30's

## Summary and Conclusions



- ***RF Weapons are Coming !***
  - Not if, . . . But when
  - Will evolve from limited device (terrorism & extortion) into a weapon of mass non-destruction
- ***Planners need IW weapon***
  - Strong doctrine requirements
  - C3I decapitation with minimal casualties
- ***Prepare to Protect Against RF Weapons!***
  - Environment is nothing more than intense/intentional EMI
  - Ability exists in E3 EW and survivability community

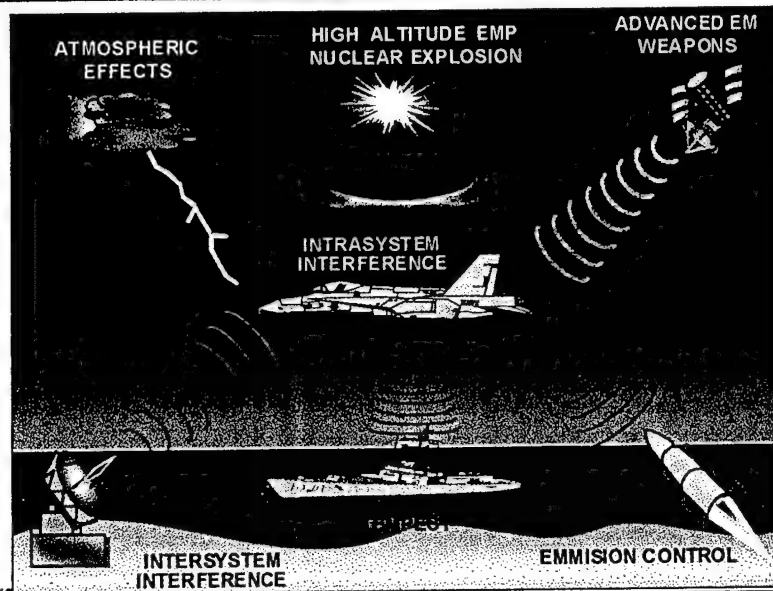


# ***RFW RDT&E TECHNOLOGY ISSUES***

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## Electromagnetic Threat Environments



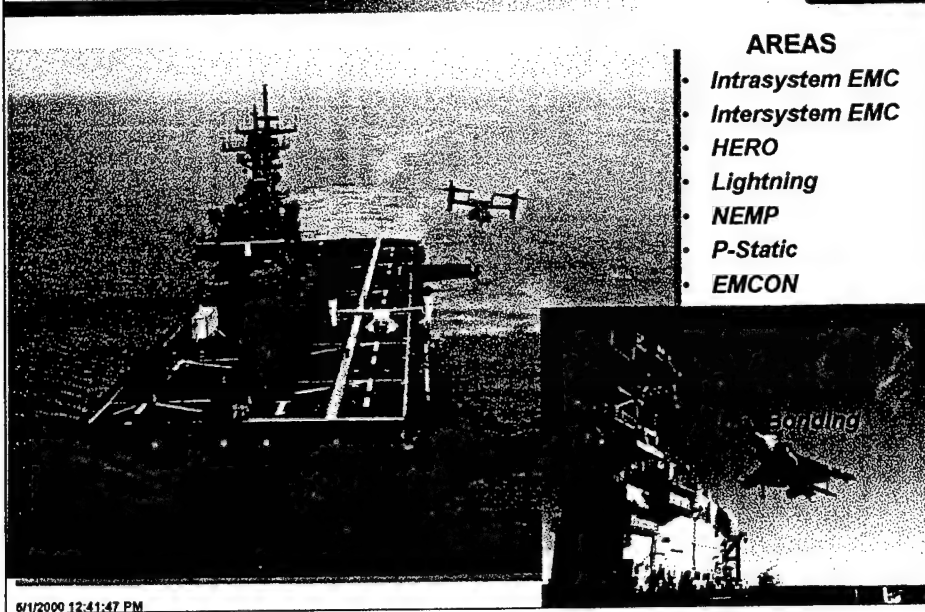
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## Navy EM Environment



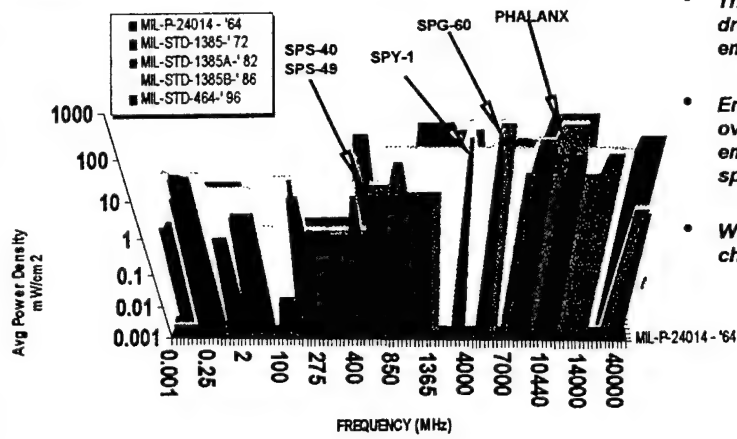
### AREAS

- *Intrasystem EMC*
- *Intersystem EMC*
- *HERO*
- *Lightning*
- *NEMP*
- *P-Static*
- *EMCON*



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## RF Environment is Hostile & Dynamic



- Threat originally driven by shipboard emitters
- Emphasis changed over time from emitter coverage to spectrum coverage
- World-wide threat changing even faster

Notional data representation for shipboard environment

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## Naval Air Approach to E<sup>3</sup>, EMP & RFW



**Navy/NAVAIR embraced EMP (and will  
Embrace RFW) as a critical element of E<sup>3</sup>**

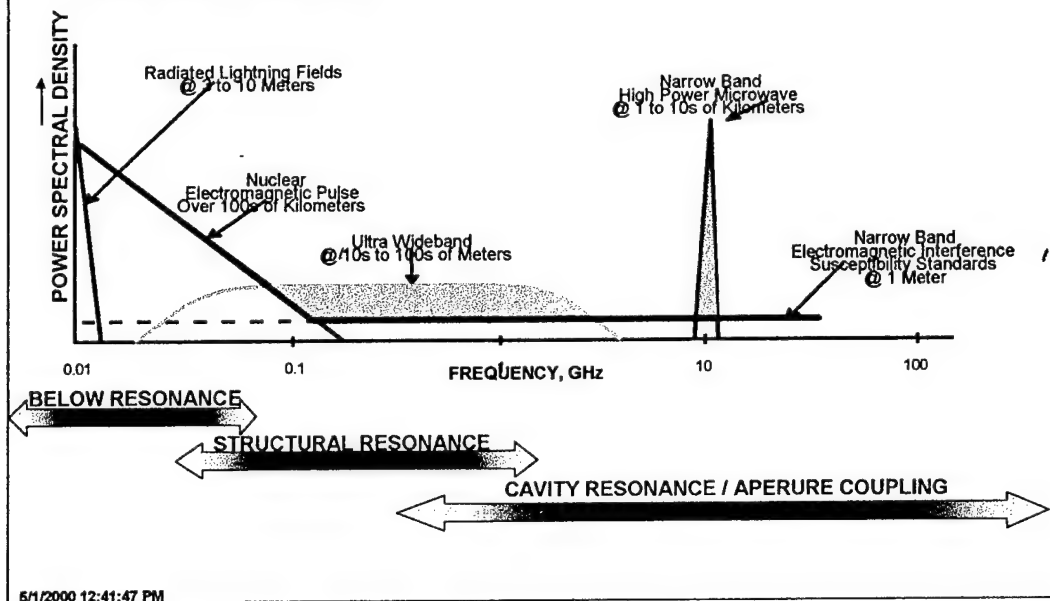
- *Seamlessly integrated EMP into E<sup>3</sup> as an  
Electromagnetic Transient (EMT)*
- *Leverage EMP and RFW S&T thrusts as a technology  
base for general E<sup>3</sup> RDT&E*
- *EMP and RFW as a balanced part of E<sup>3</sup>*

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## AMPLITUDE AND FREQUENCY RELATIONSHIPS OF VARIOUS ELECTROMAGNETIC THREATS



### • Range vs lethality



This slide reminds us that since most notional RF weapons could have higher frequency content, we may become concerned about different coupling modes.

If you compare an RF weapon with a non RF weapon with similar characteristics the coupling modes should be similar.

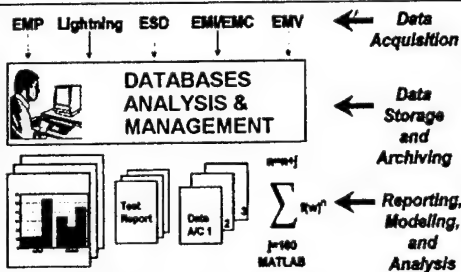
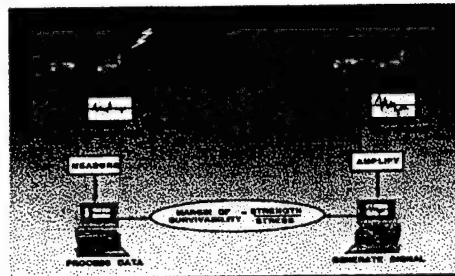
This slide also highlights the issue of intent. The difference between a radar and a weapon could easily be whether malice is involved. the system under assault is an antenna.

## E<sup>3</sup> RDT&E Process



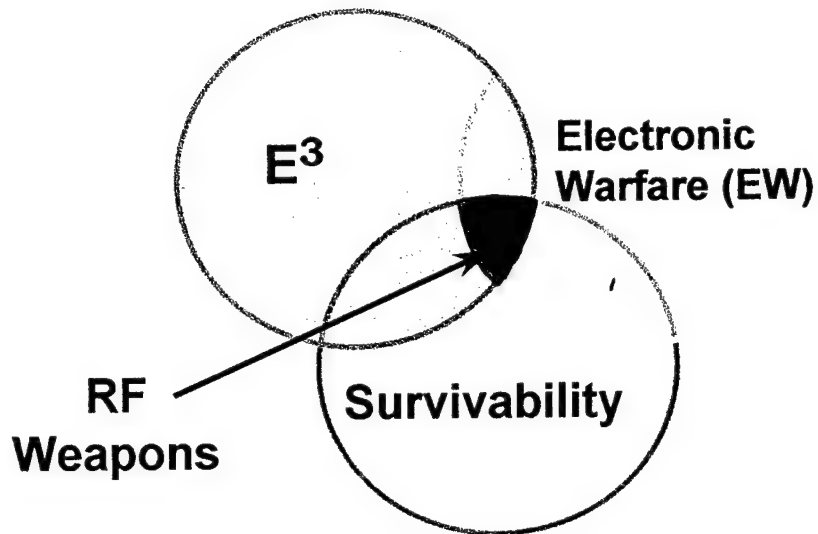
### Approach

- Enormous # of E<sup>3</sup> Issues, a very complex test object, and limited resources (time, \$)
- Source-Victim (Qualitative) Assessments for most EMC/EMI
- Margin (Quantitative) Assessments for HERO & EMP
- In house capability and technology to perform research, investigations and troubleshooting



- EM Modeling and Simulation capability
- Extensive Data Acquisition and Processing Capability (EM Transients)
  - Over 100 Test Points Instrumented simultaneously
  - 100's of unique measurements per day
  - real-time processing and Data Mgmt
- Full suite of E3 instrumentation

## Relationship Between RF Weapons Disciplines



( Naval Aviation Acquisition Model )

EW traditionally in-band and requires knowledge of systems being assaulted EM Weapons more Brute force and out-of-band

EW effects stop when EW emitter is turned off RF weapons effects remain

Other services or agencies may use another model for example the army may have a large ordnance area for RF munitions

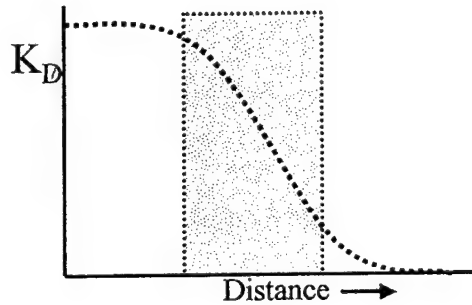
Both Offensive and Defensive

E3 is concerned with Protection, lethality, fratricide

# System Survivability



- *Determining Survivability/Vulnerability*
- *Estimation of Meaningful Distance for Likely vs. Unlikely Effects*



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Include Theory of System Survivability

Describe difference between LTF Survivability ( $P_k \times P_{k/h}$ ) and EM Survivability.



## How do we protect against RF Weapons



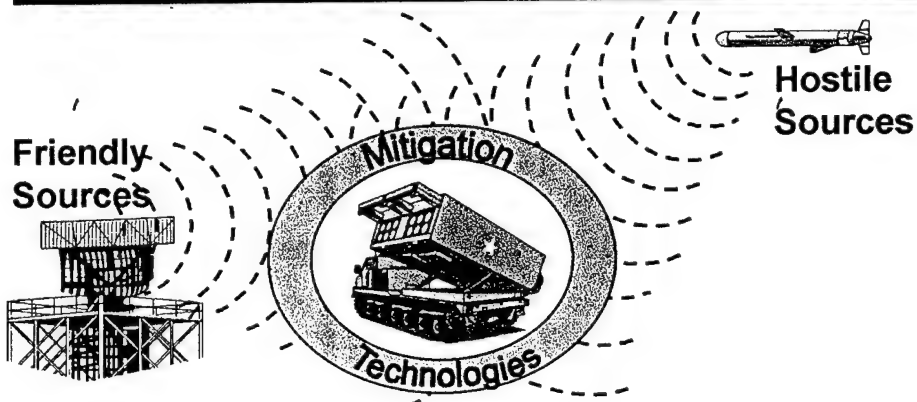
- ***Bonding***
- ***Grounding***
- ***Shielding***
- ***Filtering***
- ***Circumvention***
  
- ***Good EMI Practices, use holistic approach***
- ***Consider RFW, EW and E3 as interrelated areas***

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# RADIO FREQUENCY INTERFERENCE MITIGATION



Development of Radio Frequency Interference Mitigation Technologies is driven by both friendly and hostile sources of interference. ATD is developing technologies to allow COTS and military electronics to operate in all RF environments.



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# Categorization of Effects



## • Test System Effects

*Any Upsets and/or Anomalies observed and recorded for systems/subsystems will be assigned a specific effect level.*

Effects Level	Response
0	No Observable Effects
1	Effects Present only During Illumination
2	Residual Effects Requiring user intervention- system function reset
3	Residual Effects Requiring user intervention- system Power recycle
4	Effects Requiring system maintenance Action
5	Physical Damage

## • Operational Impact

*How will the aggregate individual effects from the various systems/subsystems impact/ affect the mission.*

Mission Category	Operational Impact of Effects
IV	None
III	Nuisance – Does Not Degrade Impact Mission Performance
II	Degraded – Requires Operator/Maintenance Intervention resulting in reduced effectiveness (Improved performance desirable)
I	Abort / Disabled - Serious Safety or mission Impact (Improved Performance required).

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## Program Approach - Objectives



- ***Assess broad range of Military, COTS and NDI systems***
  - From - simple electronic devices
  - To - complex Integrated Weapons Systems
- ***Use straightforward classic Operational T&E approach***
- ***Restrict assessments to operationally relevant scenarios for Ultrawideband terrorist threats***

***This is a Test Program, NOT a Research Program***

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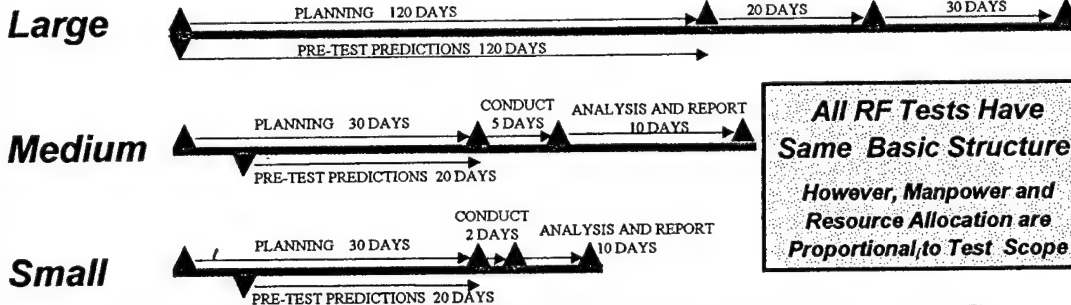
### Program Approach

This program will assess the survivability of a broad range of Military, Commercial Off-The-Shelf and Non-developmental systems. The intended test objects will range from small hand held devices such as cellular phones and handheld GPS to large complex integrated weapons systems.

# Test Methodology



## • Scope of Testing (by Test Object Complexity)



**All RF Tests Have Same Basic Structure, However, Manpower and Resource Allocation are Proportional to Test Scope**

MANPOWER and RESOURCE ALLOCATION			
Test management	Man hrs	Test Object Support	Facility Resources
Planning	Test Object Survey	Ferrying	Pulser Operation
Safety	Determine Critical Systems	On-Site Logistics	Instrumentation
Security	Determine Critical Paths	Safety	Support
Operating Procedures	Circuit Analysis	Security	Maintenance
Pre-Test Predictions	Select Points	System Operation	Repair
Analysis	Load Parameters	Procedures	Safety
Reporting	Run Models	check lists	Security
		Inerting	Physical Data
		BED Setting	User Spaces
			Shielded Enclosures
			Office Spaces
TOTAL MANHOURS	TOTAL TEST MANHOURS		

**TEST OBJECT RESOURCE ALLOCATION**  
 Ferrying to/from \_ WEEKS  
 Set-up \_ WEEK  
 Test Time \_ WEEKS  
 Post Test Checkout \_ WEEK  
 \_ WEEKS Total hours of system operation

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This table is intended to be generic and not representative of any specific test. Mike Grothous and Sam Frazier agree in principle that the scope of each type of assessment is proportionally adequate to foster discussion.

## Test Setup

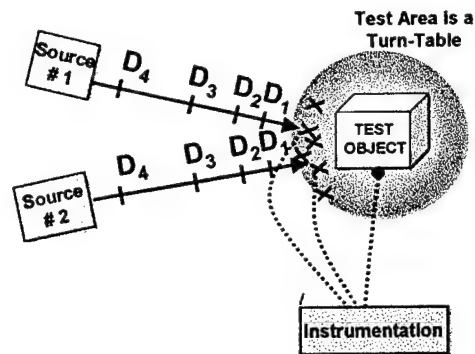


### Typical RFW Test Setup Scenarios ( Controlled Variables )

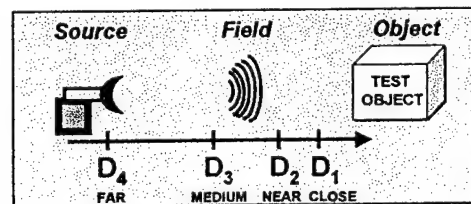
- Source Output
  - Field Strength (Distance)
  - Rep Rate / Burst Rate
- Scenario
  - Polarization
  - Aspect Angle / Elevation
- Test Object Modes

### Instrumentation

- Source Parameters
- Field Characteristics
- Test Object response
  - Visual Response
  - Electromagnetic Response



SOURCE Waveform(s)	RANGE (Distance)	AZIMUTH (Turntable Rotation)
S1	D1	A1*
S2	D2	A2
S3	D3	A3
...	...	...



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Nwwd to create MATRIX which shows general scope of test through phases

Sources

Intensity

Waveform

Rep rate

Test Object

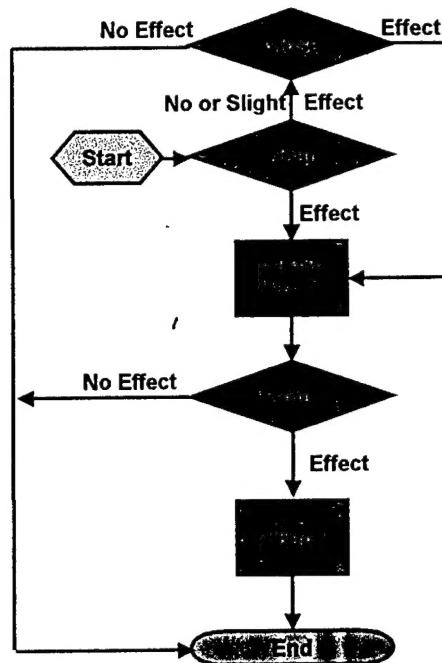
Modes

Scenario

Polarization

Angle of Incidence

# Test Object Exposure Protocol



## • Standard Test Object Exposure Protocol

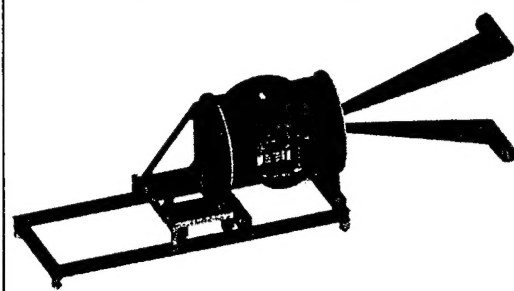
- Start Exposure at Near
- If little or no effect move to Close
- If no Effect, End
- If Effects, Reduce exposure parameters set ( $\eta$ ) based on optimum coupling/effects
- Move to Medium
- If Effects, End
- If no effects move to Far
- After Far, End Test Sequence

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# Typical Ultrawideband RF Threat Source



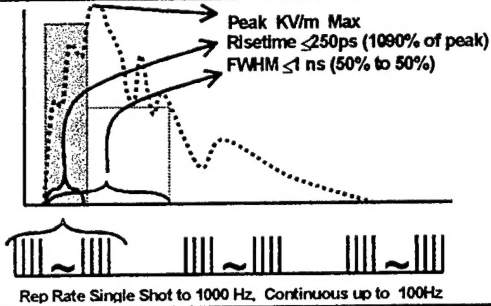
- **ALL Sources are Ultrawideband time-domain radiators**
  - high peak power low average power
  - fast-rise pulse shape
  - high repetition rates
- **Each has unique features**
  - waveform attributes
  - tunability
  - etc.



## Performance Parameters

- **Electric Field is the Parameter usually Measured**
- **Output can be 100's KV/m close to antenna**
- **Rise-time 100's of Picosecs. (10 to 90 % of peak)**
- **Full Width Half Max (FWHM) Peak to 50%~ less than a nanosec.**
- **Rep-rate Single-shot to KiloHertz**
- **Continuous operation up to 100 of Hertz**

No single system May possess all above attributes



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## Other Systems



### *COTS/NDI under consideration*

- *Computer*
- *GPS*
- *Medical Life Support (pacemaker)*
- *Wireless / Cellular*
- *Civilian Emergency Communications NET*
- *Physical Security Devices*
- *Pagers*
- *Digital Phones*
- *A/C Flight Controller*
- *Video Conf. Equip*

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